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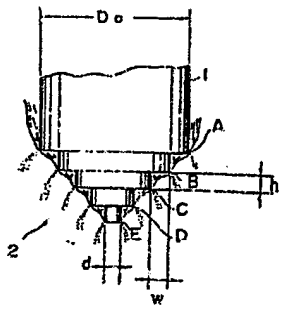
(54) Vibrating element for ultrasonic atomization.

(57) A vibrating element (1) for the ultrasonic atomization of liquid is formed around a periphery with steps having edges (A, B, C, D, E) over which a film of the liquid flows to be atomized at each edge. To improve the spray angle and the quantity of liquid sprayed, the height (h) and width (w) dimensions of each step is chosen in accordance with the wave length of ultrasonic vibration to be imparted to the vibrating element.

FIG.1



EP 0 202 100 A1

Vibrating Element for Ultrasonic Atomization

Technical Field

This invention relates generally to an ultrasonic atomizing apparatus such as an ultrasonic injection nozzle, and particularly to a vibrating element suitable for use on an ultrasonic atomizing apparatus for atomizing liquid intermittently or continuously, such atomizing apparatus including (1) automobile fuel injection apparatus such as electronically controlled gasoline injection valves or electronically controlled diesel fuel injection valves, (2) fuel nozzles for use with a gas turbine, (3) burners for use with industrial, commercial and domestic boilers, heating furnaces and stoves, (4) industrial liquid atomizers, drying atomizers for drying liquid materials such as foods, medicines, agricultural chemicals, fertilizers and the like, and spray heads for controlling temperature and humidity, atomizers for calcining powders (pelletizing ceramics), spray coaters, and reaction promoting devices, and (5) liquid atomizers for uses other than industrial use, such as spreaders for agricultural chemicals and antiseptic solution.

Background Art

Pressure atomizing burners or liquid atomizers have been used to spray or atomize liquid in the various fields as mentioned above. (The term "liquid" herein used is

int nded to mean not only liquid but also liquid materials such as solutions, suspensions and the like.) Injection nozzles used with such spray burners or liquid atomizers are adapted to atomize the liquid by the shearing action between the liquid as discharged through the nozzles and the ambient air (atmospheric air). Thus, atomization of supply liquid requires increased pressure to supply liquid, resulting in requiring complicated and large-sized liquid supplying means such as pumps and piping.

Furthermore, the regulation of the flow rate of the injection is effected either by varying the pressure of the supply liquid or by varying the area of the nozzle opening. However, the former method provides poor atomization at a low flow rate (low pressure), as a remedy for which air or steam has additionally been used on medium or large-sized boilers to enhance the atomization of liquid fuel, requiring more and more complicated and enlarged apparatus. On the other hand, the latter method requires an extremely intricate construction of nozzle which is difficult to control and maintain.

In order to overcome the drawbacks to such prior art injection nozzles, attempts have been made to impart ultrasonic waves to liquid material while injecting it out through the jet of the injection nozzle under pressure.

However, the conventional ultrasonic liquid injecting

nozzle has so small capacity for spraying that it is unsuitable for use as such injection nozzle as described above which required a large amount of atomized liquid.

As a result of extensive researches and experiments on the ultrasonic liquid atomizing mechanism and the configuration of the ultrasonic vibrating element in an attempt to achieve atomization of a large amount of liquid, the present inventors have discovered that a large quantity of liquid may be atomized by forming an edged portion at the end of an ultrasonic vibrating element and delivering liquid to and along said edged portion in a film form, and have proposed an ultrasonic injection method and injection nozzle as disclosed in EP-A-85 30 2674.8.

In order to provide a vibrating element for ultrasonic atomization which is capable of spray spreading liquid over a wider angle, and delivering and spraying or injecting a larger quantity of liquid, the present invention provides a vibrating element for ultrasonic atomization formed around its periphery with an edged portion having one

or more steps, said edged portion being supplied with liquid to atomize said liquid, characterized by the height (h) and width (w) of each step being such that

$$0.2 \text{ mm} \leq h \leq \lambda/4 \text{ and}$$

$$0.2 \text{ mm} \leq h \leq \lambda/4$$

wherein λ is the wave length of the ultrasonic waves. According to a preferred embodiment of this invention, the height (h) and width (w) of each step of the edged portion are such that $1 \leq h/w \leq 10$.

Specific embodiments of the present invention will now be described by way of example and not by way of limitation with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a fragmentary front view of one embodiment of the vibrating element for ultrasonic atomization according to the present invention;

Fig. 2 is a cross-sectional view of an ultrasonic atomizing apparatus incorporating the vibrating element for ultrasonic atomization according to this invention;

Figs. 3 to 5 are fragmentary front views of alternate embodiments of the vibrating element for ultrasonic atomization according to this invention.

Description of the Embodiments

First, one form of ultrasonic injection nozzle with which the vibrating element according to the present invention

may be employ d will be described with reference to Fig. 2.

While the present invention is suitably applicable to atomizing apparatus for various uses, it will herein be described with reference to a fuel nozzle for a gas turbine.

Referring to Fig. 2, an injection nozzle which is a fuel nozzle 10 for a gas turbine in the illustrated embodiment includes a generally cylindrical elongated valve housing 8 having a central bore 6 extending centrally therethrough. A vibrating element 1 according to this invention is disposed extending through the central bore 6 of the valve housing 8. The vibrating element 1 includes an upper body portion 1a, an elongated cylindrical vibrator shank 1b having a diameter smaller than that of the body portion 1a, and a transition portion 1c connecting the body portion 1a and shank 1b. The body portion 1a has an enlarged diameter flange 1d which is attached to the valve housing 8 by a shoulder 12 formed in the upper end of the valve housing 8 and an annular vibrator retainer 14 fastened to the upper end face of the valve housing by bolts (not shown).

severed and at mized at each edge. The fuel is first partially atomized at the edge (A) of the first step, and the excess portion of the fuel which has not been handled at the edge (A) of the first step is fed successively through the second step edge (B), the third step edge (C) and so forth to be handled thereby. At a higher flow rate of fuel requiring larger effective areas for atomization, more stepped edges are required. At a lower flow rate, however, a smaller number of steps are required before the atomization is completed. With the vibrating element 1 according to this invention, the number of steps required for atomization will vary with changes in the flow rate so as to ensure generally uniform conditions such as the thickness of liquid film at the location of each step where the atomization takes place, resulting in uniform particle shape and size of the droplets being atomized. The vibrating element according to this invention provides for a full range of flow rates usually required for atomization so that atomization of various types of liquid materials may be accomplished, whether it may be on an intermittent basis or on a continuous basis.

It will be appreciated from the foregoing that the height (h) and width (w) of the steps of the edged portion shown in Fig. 1 is such that it may act to render the liquid filmy and to dam the liquid flow. Researches and experiments conducted by the present inventors have shown that the height (h) and

width (w) of the steps of the edged portion must be kept in a predetermined range as follows in order to effect atomization of supplied liquid in a large quantity:

$$0.2 \text{ mm} \leq h \leq \lambda/4 \qquad (1)$$

$$0.2 \text{ mm} \leq w \leq \lambda/4 \qquad (2)$$

wherein λ is the wavelength of the ultrasonic waves.

In a preferred embodiment of this invention the height (h) and width (w) that $1 \leq h/w \leq 10$. Particularly for the vibrating element of the configuration as illustrated in Fig. 1 the height (h) is preferably less than 4 mm. The wavelength of the ultrasonic is typically 5 cm to 50 cm depending upon the material (such as inconnel, titanium or the like) of which the vibrating element is made.

The output of the ultrasonic generator the vibrating element is the order of 10 W, and the amplitude and frequency of vibration of the vibrating element are in the ranges of 30 to 70 μm and 20 to 50 KHz, respectively. The diameter (D) of the vibrating element is suitably in the range of $\lambda/10$ to $\lambda/4$. The greater the amplitude of vibration and the diameter (D), the greater the capacity for handling the liquid.

vibrating element of the present invention is not limited to the configuration as shown in Fig. 1, but may take various forms as shown in Fig. 3 to 5.

The forward end of the vibrating element shown in Fig. 3 is formed with an edged portion 2' having one or more steps of equal diameter, three steps (A'), (B'), (C') in the illustrated embodiment. The shape of the edged portion 2' as viewed in the direction of the arrow (X) is not limited to a circular shape, but may be triangular, square or some other polygonal shape. According to the present invention, the height (h) and width (w) of the steps of the edged portion 2' are sized as defined by the equations (1) and (2) as indicated hereinabove. The angle (α) may be suitably selected. The angle of injection (angle of injection spread) may be adjusted by selecting the height (h), width (w) and angle (α) as desired.

While the edged portion 2' has been described as comprising protrusions (A'), (B') and (C') which are all of the same angular shape, those protrusions need not be of angular shape but may be of any other shape, provided that they are formed around their outer peripheries with edges.

Figs. 4 and 5 illustrate further embodiments of this invention in which the multi-stepped edged portion 2" or 2''' has one or more steps is formed around an inner periphery of the forward end of the vibrating element 1. Again, in these embodiments, satisfactory atomization may be achieved if the aforesaid conditions are satisfied. Of course, in these embodiments, liquid is fed to the edged portion through a liquid supply passage 4' formed through the vibrating element.

An example of various parameters and dimensions of an ultrasonic atomizing apparatus according to this invention for the injection of liquid fuel is as follows: It has been found that such construction provides for atomization in a very large amount.

Output of ultrasonic vibration generating means: 10 watts

Amplitude of vibration of vibrating element: 30 μm

Frequency of vibration of vibrating element: 38 KHz

Geometry of edged portion (embodiment of Fig. 1)

- Width (w) of edged portion: 0.5 mm
- (diameter D of vibrating element edged portion)
- First step: 7 mm in diameter (Do)
- Second step: 6 mm in diameter
- Third step: 5 mm in diameter
- Fourth step: 4 mm in diameter
- Fifth step: 3 mm in diameter (d)
- Height of each step: 2 mm

Fuel Type of oil: Gas oil

Flow rate: $\sim$ 0.06 cm^3 per injection

Injection pressure: 1 $\sim$ 70 kg/cm^2

Temperature: normal temperature

Material of which the vibrating element is made: Titanium

Effects of the Invention

As is described h reinabove, the vibrating element having a geometry defined according to the present invention is capable of providing a wider angle of spray spread and achieving atomization in a large amount, and thereby enables the provision of an ultrasonic atomizing apparatus capable of accomplishing consistent atomization in that there is no change in the conditions of atomization (flow rate and particle size) depending upon the properties, particularly viscosity of the supply liquid.

Claims:

1) A vibrating element for ultrasonic atomization which is formed around its periphery with a stepped edged portion having one or more steps, said edged portion being supplied with liquid to atomize said liquid, characterized by the height (h) and width (w) of each step being such that

$$0.2 \text{ mm} \leq h \leq \lambda/4 \text{ and}$$

$$0.2 \text{ mm} \leq w \leq \lambda/4$$

wherein λ is the wave length of the ultrasonic waves.

2) The vibrating element for ultrasonic injection according to claim 1 wherein the height (h) and width (w) of each step of the edged portion is such that

$$1 \leq h/w \leq 10.$$

FIG.1

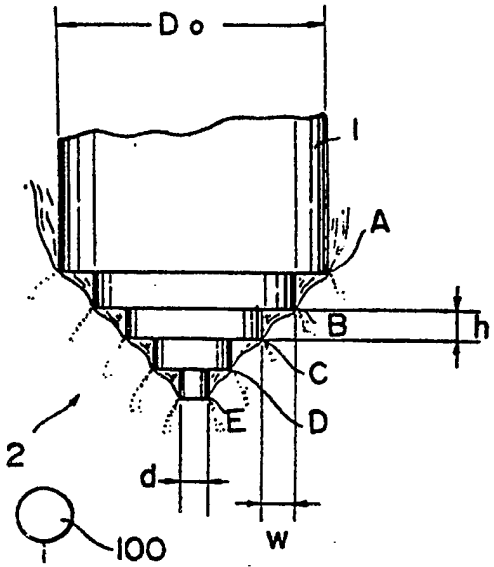


FIG.2

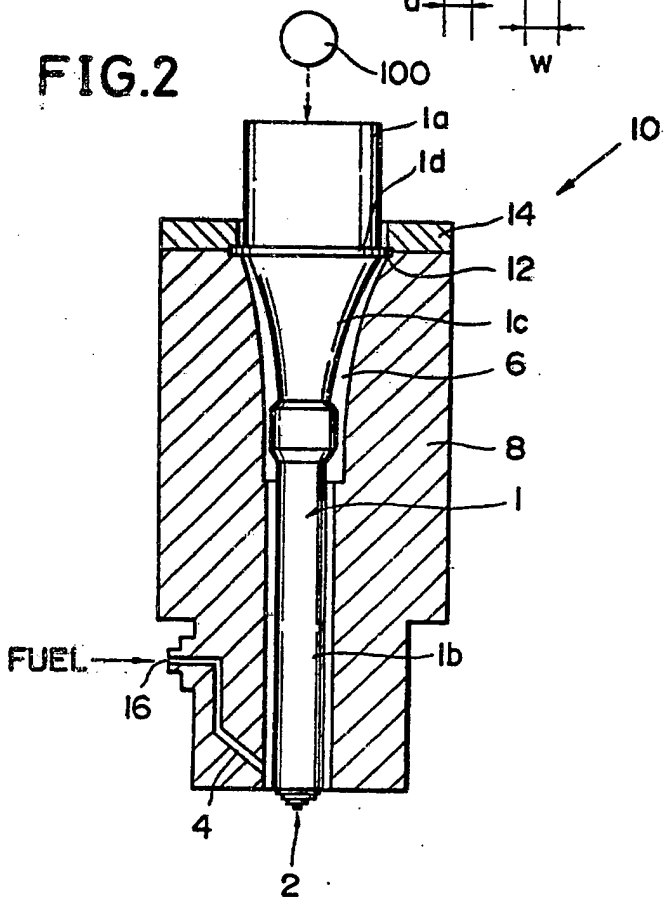


FIG.3

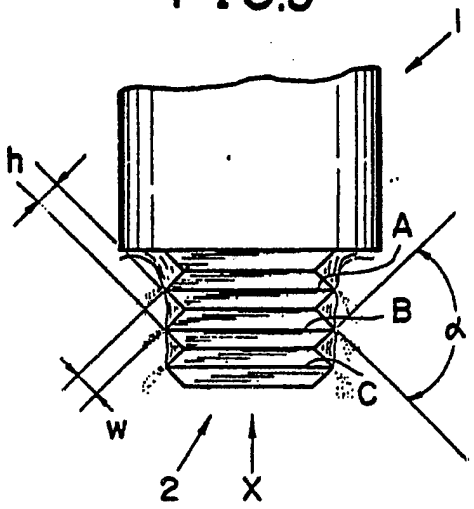


FIG.4

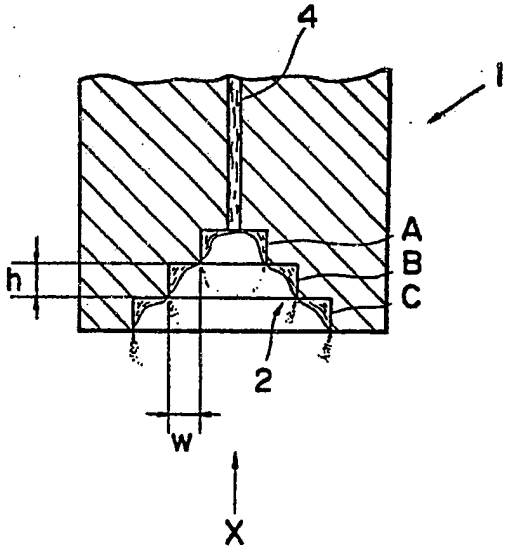
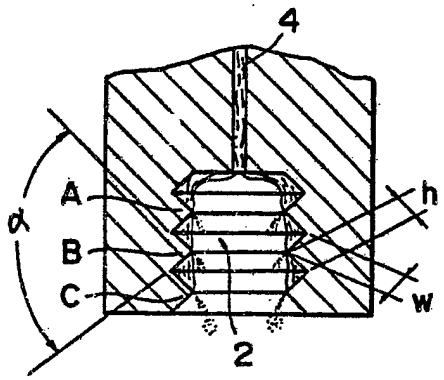


FIG.5



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EUROPEAN SEARCH REPORT

0202100
Application number

EP 86 30 3613

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
A	US-A-4 474 326 (TAKAHASHI) * Column 3, line 63 - column 7, line 56; figures 2-9 *	1	B 05 B 17/06 F 02 M 27/08 F 23 D 11/34
A	GB-A-2 126 923 (LECHLER) * Page 2, lines 3-76; figures *	1	
A	US-A-3 400 892 (ENSMINGER) * Whole document *	1	
A	US-A-3 373 752 (KIYOSHI INOUE) * Column 5, lines 5-25; figure 5 *	1	
A	FR-A-1 271 341 (HITACHI) * Page 1, paragraph 3; page 3, paragraphs 5,6; figures 8,9 *	1	TECHNICAL FIELDS SEARCHED (Int Cl 4) B 05 B F 02 M F 23 D
A	DE-C- 852 275 (BORN) * Whole document *	1	
D,P A	EP-A-0 159 189 (TOA) * Whole document *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-08-1986	HAKHVERDI M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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